Adapting an IXO Grating Spectrometer for Polarimetry

Herman L. Marshall, Kendrah Murphy, Norbert Schulz, Ralf Heilman, Kevin Jenks, & Eric Marshall
MIT Kavli Institute

MIT Kavli Institute for Astrophysics and Space Research

Abstract

A novel approach for measuring linear X-ray polarization over a broad-band using conventional imaging optics and cameras is described. The International X-ray Observatory's grating spectrometer is used to disperse soft X-rays radially from the telescope axis. A set of laterally graded multilayer-coated flat mirrors redirect the dispersed X-rays to the focal plane at large angle to the incoming beam. The intensity variation with position angle is measured to determine three Stokes parameters: I, Q, and U. The multilayer optics are laterally graded in order to match the dispersion of the gratings, taking advantage of high multilayer reflectivities to achieve modulation factors over 50% over the entire 0.2 to 0.8 keV band. This approach can be used with the IXO X-ray grating spectrometer.

Soft X-ray Polarimetry with IXO

- A new optical configuration produces polarized X-rays at an existing focal plane
- The system has a very wide bandpass with high efficiency and modulation factor
- Adapted to the focal plane of the Grating Spectrometer
- High efficiency in 0th order gives direct imaging in addition
- For PKS 2155-302, the minimum detectable polarization (MDP) would be 3-7% in 10 ks in each of 4 spectral bands (20-30 Å, 30-40 Å, 40-50 Å, 50-60 Å)
- For NS RX J0720.4-3125, MDP = 5-8% in 10 pulse phase bins in each of 3 bands (20-30 Å, 30-40 Å, 40-50 Å) for a 200 ks observation

Leroy

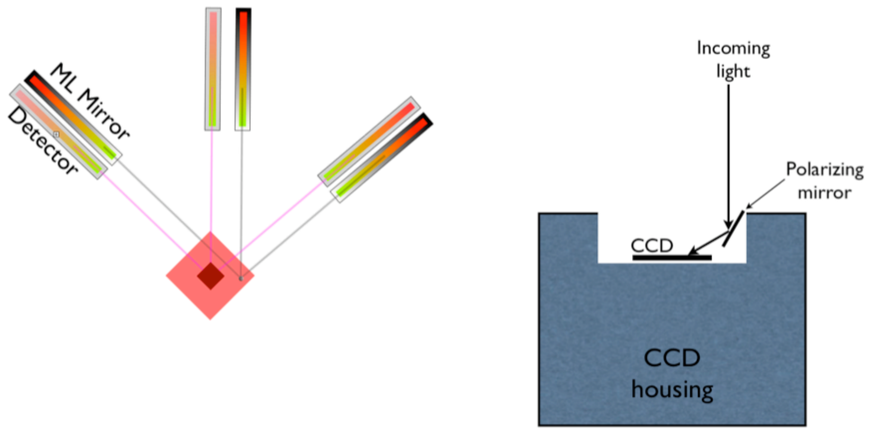


Fig. 1: Schematic of the focal plane of the International X-ray Observatory, as modified for soft X-ray polarimetry. Two extra readout arrays provide the extra information needed to measure the Stokes parameters. With offset pointing, the multilayer coated mirrors need not move.

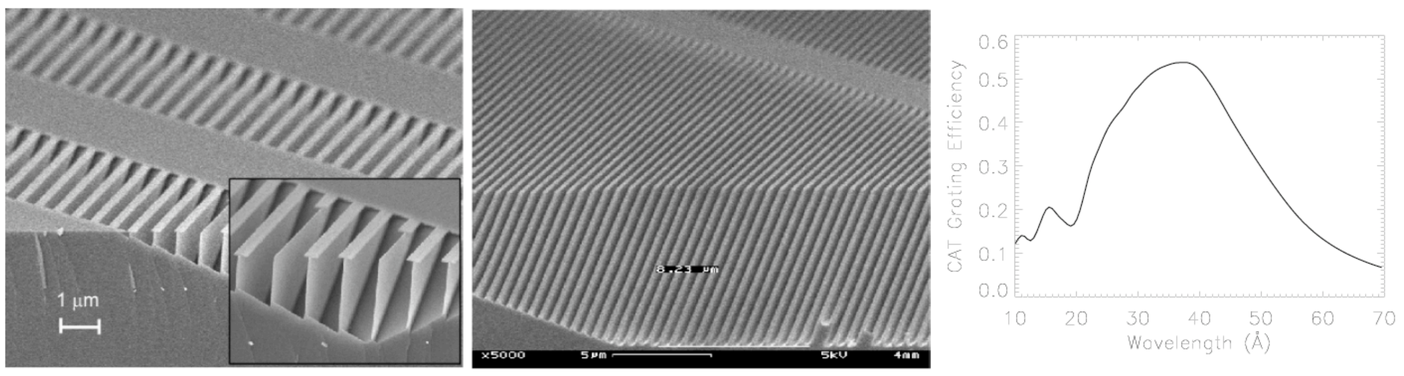


Fig. 2: Prototype critical angle transmission (CAT) gratings. The gratings are blazed to provide high efficiency in one order (above right). Images are from a white paper, proposing to use these novel gratings for a transmission grating spectrometer on Constellation X (see also Flanagan et al. 2007, SPIE, 6688-27) and now proposed for IXO (see Heilmann et al. poster). For this application, the CAT gratings would have a period of 100 nm, lengths of 3.5 µ, widths of 15 nm, and would be tilted at 0.95° to the vertical. This polarimetry concept could also be used eith off-plane gratings in a reflection spectrometer design.

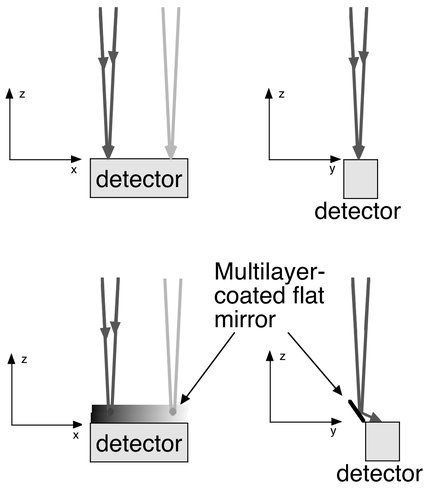


Fig. 3: *Top:* Schematic of a single detector receiving dispersed X-rays from gratings behind the telescope, as in a normal IXO grating spectrometer configuration. Two views are shown, where the z-axis is along the telescope axis. The spectrometer dispersion axis is approximately parallel to the x-axis, along the surface of the detector (which is segmented to follow the Rowland circle). The cross-dispersion direction is parallel to the y-axis. Two different wavelengths of X-rays arrive at the focal plane, differing in x according to the grating dispersion relation. Only one of these is shown in the right-hand view. *Bottom:* Same telescope and grating optics but now a polarizing flat has been added. The flat is placed at an angle of about 65° to the incoming X-rays to reduce the reflectivity of p-polarized X-rays. The multilayer coating period varies with position along the x-axis, tuned to reflect short wavelengths at low x and long wavelengths at large x. With offset pointing, the source spectra can be positioned to strike the multilayer-coated flat. Several spectrometers are required at different orientations to measure the 3 Stokes parameters.

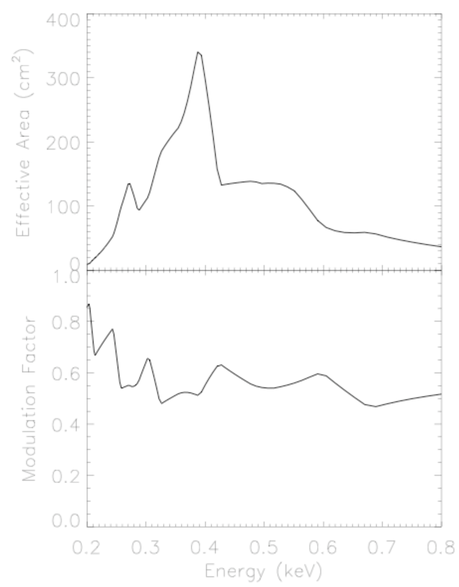
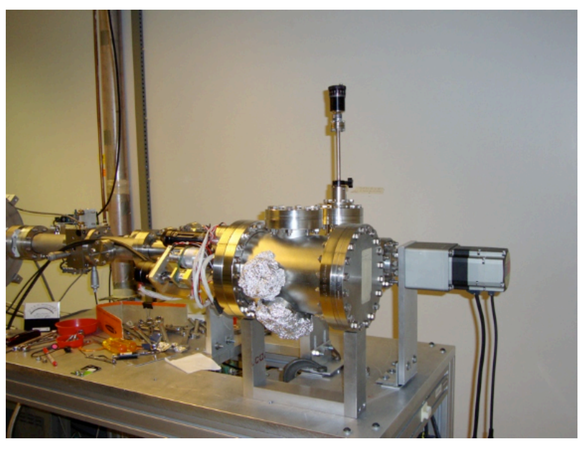
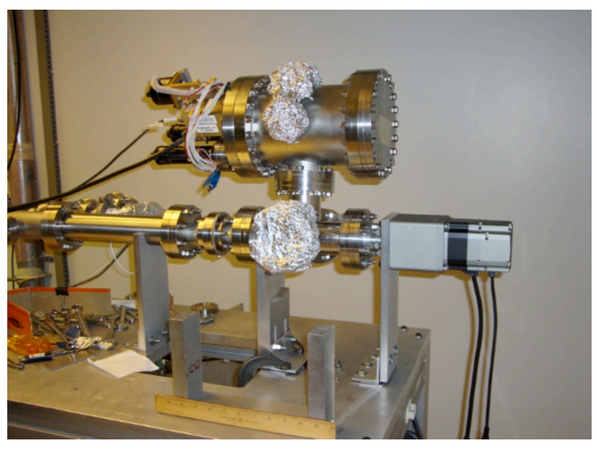


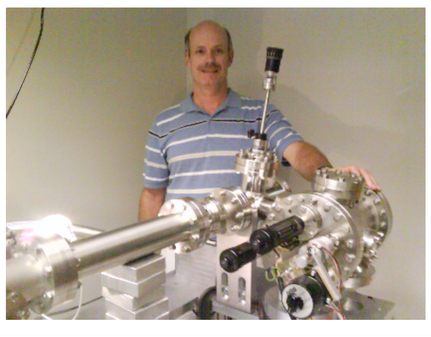
Fig. 4: Effective area (top) and polarization modulation factor (bottom) for this design where one IXO mirror sector is used with a CCD detector and a thin optical blocking filter. An effective area of over 100 cm² can be achieved over most of the 0.2-0.8 keV bandpass.

The MIT Soft X-ray Polarization Laboratory



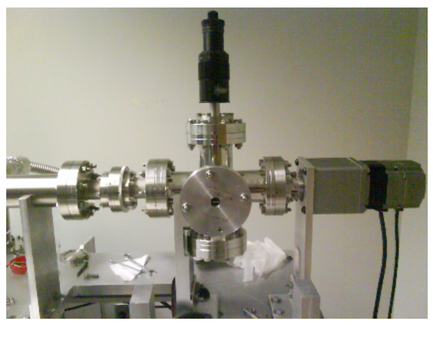


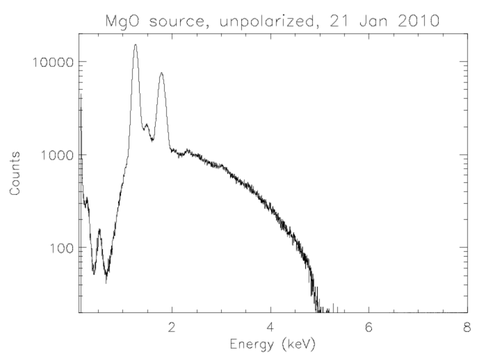
Above: The polarizing X-ray source is rotated to two different angles, rotating the polarization of the output X-rays by 90°. The CCD detector is 17 m to the left.



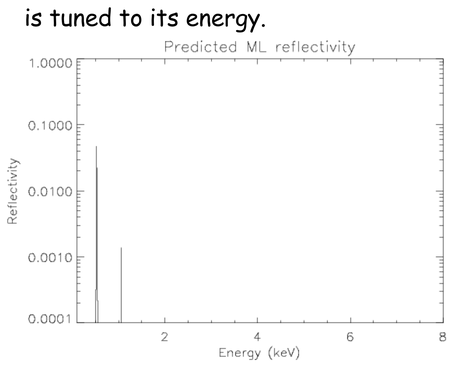
Left: the X-ray source is shown with a human to show scale.

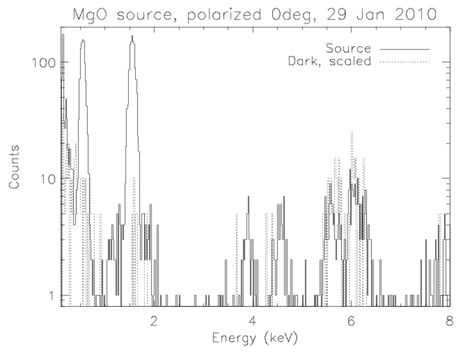
Right: a new mirror manipulator has been installed and a laser alignment plate was mounted on the port where the X-ray source was.





Above: CCD spectrum of the source without the polarizing mirror in place.
Below, left: predicted reflectivity of the multilayer mirror in the system.
Below, right: example CCD spectrum after one reflection off of the multilayer coated mirror. The Mg-K and W-M lines are not detectable but an Al-K line appears due to fluorescence off of the mirror holder. The O-K line is strong because the multilayer is tuned to its energy.





This work was supported in part under Smithsonian Astrophysical Observatory (SAO) contract SVI-73016 to MIT for the Chandra X-Ray Center (CXC) and an MIT Kavli Instrumentation Grant.